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INSTRUCTION MANUAL

E601

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J-OMEGA COMPANY

TYPE 21B VOLT-OHMMETER
OR
TYPE 21BV VOLTMETER

Serial No._____

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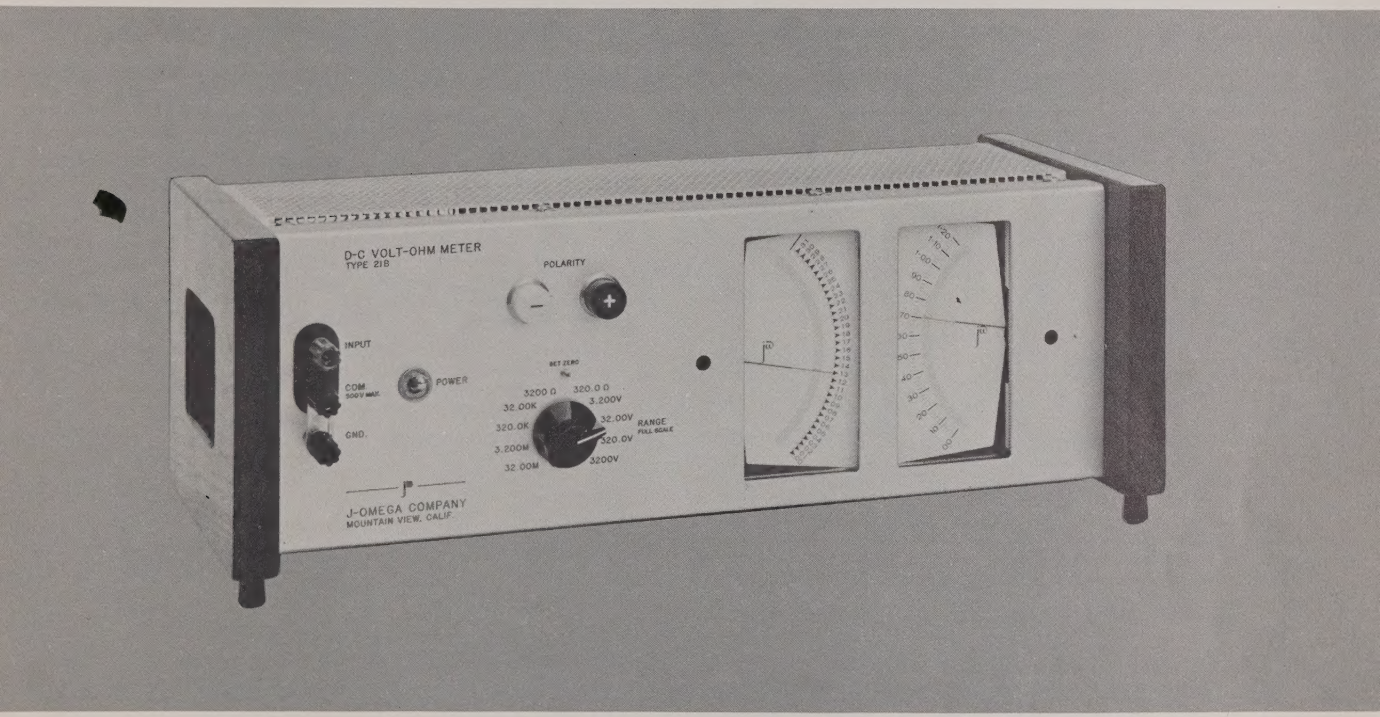
TYPE 21B DIGITAL/ANALOG 0.1% VOLT-OHMMETER

For Fast, Precise Measurements



USES

GENERAL LAB INSTRUMENT — High accuracy combined with unusually broad voltage and resistance ranges.

TWT VOLTAGE MEASURMENTS — 3200 volt range permits direct use for helix voltages, etc.

POWER SUPPLY ADJUSTMENTS AND MONITORING — Resolution in millivolts with visual analog "follow" for observing power supply drift.

RECEIVING INSPECTION — Single control operation, automatic polarity display, isolated input provide desirable measuring speed and versatility.

SYSTEMS INSTALLATIONS — Available as a compact, rack mounting unit with input terminals at front or rear.

CIRCUIT DESIGN — High input impedance, dual function, fast response fulfill suitability as a useful design tool.

PRODUCTION LINE TESTS — Constant display, digital/analog readout and linear scales contribute to fast, foolproof testing.

FEATURES

DIGITAL/ANALOG MEASUREMENT — The combination offers the user advantages of both techniques.

CONSTANT DISPLAY — Magnitude and direction of input changes are seen immediately; no sampling time delay.

AUTOMATIC OPERATION — No balancing operation as with potentiometric-type instruments; polarity indication is automatic also.

VOLTAGE AND RESISTANCE — Only instrument in its class to offer both types of measurement in a single package.

WIDE MEASURING RANGE — Full scale ranges from 3.2 volts to 3200 volts; 320 ohms to 32 megohms.

HIGH RESOLUTION — Exceeds .03% of full scale; 1 millivolt on 3.2 volt range.

FAST READOUT — All voltage and resistance readings made from same close-positioned linear scales; no scale selection.

LOW VOLTAGE OPTION — Instrument also available as voltmeter alone with an additional 320 millivolt full scale range.

DESCRIPTION

Two objective questions about the J-Omega 21B in a prospective user's mind often are — what is a digital/analog volt-ohmmeter and, what are its advantages?

The Type 21B measures and displays about 85 to 95% of an unknown input value in true digital form and indicates any remaining increment as an analog vernier that is immediately responsive to dynamic characteristics of the input. Users of the 21B find its combination of digital and analog techniques offer several practical advantages when compared with other instruments of either the straight analog or digital types in that: a single control selects both function and range for any operation; there is no null-balancing procedure; readout is fast and foolproof, since the same pair of **linear** scales is used for all measurements; a changing input does not produce unreadable digit-hunting common to full-digital instruments; and the 21B does not sample the input but instead, measures and displays it continuously.

These factors provide exceptional "operating rapport" when using the 21B because the measuring feel of an analog instrument is retained, coupled with the operating simplicity and readout ease of digital equipment; this becomes quite apparent when making the first few measurements with the instrument. The Type 21B Digital/Analog Volt-ohmmeter is a general purpose measuring device combining the accuracy of a Standards lab instrument with the ruggedness and versatility of an "everyday" multi-range meter. Its proper uses include both the engineer's bench and production line where it can be used for routine measurements by semi-skilled persons even when its accuracy capabilities are needed only occasionally.

Two conventional D'Arsonval movements are used, and so arranged that the "resolving power" of one acts to multiply the resolution and accuracy of the other. When an input is applied to the 21B, the right-hand indicator smoothly moves up the scale until, in the region of full scale, the digital (left) indicator abruptly moves up one step and the right-hand meter drops back to the bottom of its scale. This process is repeated very rapidly until the correct reading is reached within about one second.

The analog meter is calibrated so that the span from 00 to 100 corresponds to 1 step of the digital indicating meter. Since the 00 to 100 span of the interpolating meter is $1/32$ of the instrument's range, this results in an improvement of resolution of the D'Arsonval movement by a factor of 32! Movement of the left-hand meter pointer is quantized so that it always points directly to one of 32 numbers (00 through 31) thus providing a true digital indication.

In designing the Type 21B emphasis was placed on reliability and simplicity. The instrument is fully transistorized except that one tube is used at the input for high input impedance with low drift and minimum circuit complexity. This tube, a common type (12AU7), is operated at reduced heater voltage and negligible plate dissipation so that its life expectancy is very long. Aside from front-panel switches and taut-band meters, the only moving parts are simple, conventional plug-in relays; paralleled contacts on these relays provide an exceptional margin of reliability. No stepping switches are used.

USING THE 21B

Operating and reading the 21B is very simple and fast. The single Function control is used initially to select the operating mode and range. Measurements are then made automatically, including color coded pilot light polarity indication.

For readout, the operator simply reads from the digital indicator and two additional figures from the right-hand indicator. A typical readout might be 23-13 or 2313. In the 3.200 voltage range, this would indicate 2.313 volts with a resolution of 1 mv or better!

When conventional accuracy (1 or 2% of full scale) is required, the instrument may be set to the highest range needed so that range switching is completely avoided. For example, work in transistor circuits might seem to call for frequent use of the 3.2 volt range but the right-hand meter resolves 10 millivolts on the 32 volt range. Thus, a single range will cover the highest voltage to be encountered while offering good accuracy on low voltages.

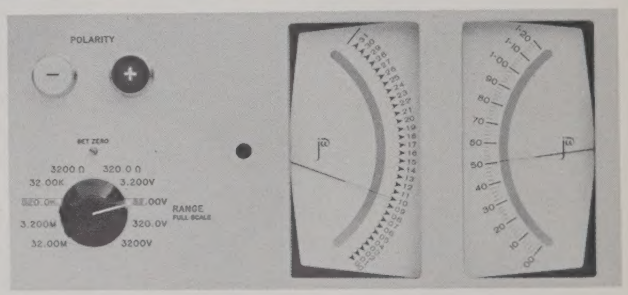
CIRCUITRY

A signal voltage proportional to the unknown or resistance is obtained from an input amplifier. This voltage (ranging from —6.4 to +6.4 volts) is applied to a binary digitizing circuit that produces a nearly equal voltage quantized in 32 very accurate steps of 0.2 volt each. The left-hand meter is fed from the quantized voltage so that it moves in discrete steps, forming a digital indicator. The second (right-hand) meter indicates the difference between the signal voltage and the quantized-voltage. It thus interpolates between the steps of the first indicator.

The instrument's circuitry is comprised of three main sections: (1) an input D-C amplifier with associated range resistors, (2) a six-stage binary digitizing circuit which provides a five bit (0 to 31) digital signal plus one bit of polarity (+ or —) information, and (3) a highly stable regulated power supply.

The input amplifier is a four stage single-loop feedback circuit in which the first and second stages are balanced. The digitizer consists of six similar stages, each composed of a balanced pair of transistors for voltage comparison and a third transistor for driving a relay. A precision resistor network, fed from an accurate reference supply, provides digital-to-analog reconversion to produce a quantized voltage approximating the input amplifier's output. The power supply reference voltage, obtained with a precision temperature-compensated Zener diode, has a temperature coefficient of approximately ±0.001%/°C.

For resistance ranges, the unknown resistor replaces the feedback resistor. A constant current applied to the amplifier input produces negligible input voltage but an output voltage proportional to the unknown resistance. Thus, a linear ohmmeter results, eliminating separate non-linear ohms scales.



SPECIFICATIONS

RANGES Four DC voltage ranges and six resistance ranges with the following full-scale values:

±3.200 volts	320.0 ohms (20 ma.)
	3.200 kilohms (2 ma.)
±32.00 volts	32.00 kilohms (200 μa.)
±320.0 volts	320.0 kilohms (20 μa.)
	3.200 megohms (2 μa.)
±3200 volts	32.00 megohms (0.2 μa.)

(320 mv. range option described below)*

ACCURACY ±0.1% of full scale or better. (The total accuracy for both resistance and voltage measurements improves linearly from ±0.1% of f.s. at the top of each range to ±.03% of f.s. at bottom of each range, i.e., accuracy of any measurement is ±.07% of reading plus ±.03% of f.s.).

INPUT IMPEDANCE 10 megohms ±0.2%

INPUT Double jack-top binding posts, isolated from case. Common terminal may be floated ±500 v above case.

DRIFT Less than 0.2% of f.s./hr. on resistance ranges and on 3.2 volt range. Less than 0.1% of f.s./hr. on other voltage ranges. Typically, drift will be less than half of these figures after 20 minute warmup. Panel zero-adjuster permits immediate drift correction.

RESPONSE TIME Approximately 1 second except on 3.2 volt and 32 megohm ranges. About 2 seconds on these two ranges.

AC REJECTION AC of 60 cps to 100 kc may be superimposed on the DC voltage to be measured if its rms value does not exceed 10% of the full scale range setting. This limit is increased to 100% for the 3.2 volt range.

DIMENSIONS Bench type: 5¾"H x 16⅝"W x 6¾"D.
Rack type: 5$\frac{31}{32}$"H x 19"W x 5⅝" D.

WEIGHT Net 9 lbs., shipping 14 lbs.

POWER 105 to 125 volts AC, 50 to 1000 cps, 25 watts.

PRICE $650.00, either bench or rack type.

OPTIONS *Modification V: Instrument supplied suitable for wider range of voltage measurements only. A fifth voltage range, 320.0 millivolts full scale, is added and the resistance ranges are omitted. Specifications are as stated above except that the 320 mv. range alone has: 1 megohm input impedance; 2.5 sec. response time; 60% AC rejection; 2 mv./hr. typical drift. Order instrument as Type 21BV. Full price is the same, $650.00.

Inputs on rear only or in parallel with front inputs, $15.00.

Supplied for operation from 220 volt power source, $20.00.

eBG and **eem** buyers' guides list J-Omega representatives. Technical aid, etc., is conveniently available to you from these representatives.

REPRESENTED BY:

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INTRODUCTION

This instruction manual covers the use and maintenance of both the 21B Volt-Ohmmeter and the 21BV Voltmeter which omits the resistance measuring function and in its place provides an additional DC voltage range of 320mv full scale.

The J-Omega Type 21B is a unique instrument that combines the circuitry and operating features of both digital and analog instruments. Four places of information are provided with an accuracy of ± 0.1% of full scale or better. The left meter indicates the digitized data, which usually comprises 85% or more of an input's value; the remaining increment is displayed in analog form by the right meter. Operation of the instrument is fully automatic, after the appropriate measuring range is selected. It is significant to note that there is no ± 1 count error factor to add to the basic accuracy statement of the instrument.

The application and handling of this instrument should be made with the reasonable respect due any precision device. In particular, care should be taken not to apply voltage in the resistance measuring mode (on the 21B these ranges are marked in red as a precaution) and secondly, avoid floating an input voltage above 500v (as noted on the instrument panel).

Due to its unusual features, the Digital/Analog 21B makes an excellent laboratory instrument for the intermittant use common to this type of application. There is no reason, however, why the instrument should not be used as an all day, month-after-month production test unit. It is designed to, and has proven to give reliable extended performance with minimum need for service and calibration in such applications.

EQUIPMENT WARRANTY

J-Omega instruments are covered by a one year warranty, the terms of which are stated below.

WARRANTY

J-Omega instruments and components thereof are warranted to be free from defects in materials and workmanship for one year from date of initial factory shipment.

We, or our authorized representatives, will repair equipment of our manufacture covered by the warranty terms on a no-charge basis to include both parts and labor.

Applications misuse, abuse of the equipment or unauthorized repair will void this warranty and our obligation to provide no-charge service. J-Omega company is not liable for consequential damages.

Prior to returning an instrument to the factory for service, please contact J-Omega Company, either directly or through our representative and indicate the nature of the difficulty being encountered. The problem may be one which can be resolved quickly and easily in the field, thereby eliminating the time loss involved in transportation to and from the factory.

When non-warranty repairs are to be made, we will notify you of the estimated charges before proceeding with the work.

OPERATING INSTRUCTIONS

Preparation

The bench version of the 21B can be placed on its bottom or, if reading convenience makes it desirable, on its back. When used in the normal position the bottom front feet which are threaded into the end blocks, can be extended about 1 1/4 inches to reduce the viewing angle. Rack mounting models fit the standard 19 inch relay rack scheme. Input connections may be located on the rear depending on whether or not this is optional feature was ordered.

Before plugging the unit to a power source, note the required nominal input voltage marked on the rear of the instrument. The standard (115 volts) instrument can be powered from AC sources providing 105 to 125 volts, 50 to 1000 cps. A 220 volt instrument is suitable for use from 210 to 250 volts, 50 to 1000 cps.

Panel Controls

Meter Zero Setting: Two mechanical zero adjustments are accessible through holes in the front panel, one next to each meter. The need to make this adjustment should be rare. This zeroing should be done when the power has been off for several minutes or more.

"POWER" Switch: The instrument is turned on by moving the lever up. Before doing so it is advisable to make sure that both meters are mechanically "zeroed" properly. After turn-on it is best to wait five minutes or more before making measurements to allow the instrument to stabilize. Maximum stability is reached after 15 to 20 minutes warmup.

"SET.ZERO" Control: After allowing time for warmup this control should be rotated so that both meters are zeroed electrically. This should be done only on the lowest (3.2 volt or 320mv) range and with the input terminals shorted (resistances up to 2 or 3 megohms are adequate "shorts"). If only one voltage range is to be used, the instrument may be zeroed on this range.

If warmup time is short before measurements are begun, zero should be checked several times during the first 15 or 20 minutes and corrected if necessary. After stabilization the zero need be checked only occasionally to correct for possible slight drift which is normal over a period of hours.

CAUTION: Do not use the "SET ZERO" adjustment to obtain offset, as errors may result. In particular, this control should not be used to compensate for ohmmeter lead resistance. Lead resistance when significant, should be measured as a separate step and subtracted from the ohms reading.

NOTE: The high resolution of this instrument can be very useful, but the operator should not be misled into making too-frequent or too-exacting adjustment of the "SET ZERO" control. Small errors may be quite visible yet negligible.

"RANGE" Switch: Select a range that is at least slightly higher than the highest anticipated input value. In the 21B this switch permits selection of both ohms (Ω, k, M) ranges and volts (V) ranges. The 21BV has volts ranges only.

CAUTION: As is the case with most ohmmeters, the 21B may be damaged by application of excessive voltage to the ohms circuitry. Be sure to use the ohms settings only when testing passive devices.

Input Terminals: The "INPUT" (red) terminal is the independent terminal when voltage is measured. It is well insulated against high voltage and leakage. For resistance measurements this terminal is positive.

The center "COM." terminal connects to the bulk of the internal circuitry and has somewhat lower insulation to the ground. Whenever possible it should be grounded to the "GND." terminal, which is connected to the case and panel. If the common terminal is to be floated from case ground, it is important that the potential between these two terminals not exceed 500 volts.

The upper two terminals of the 21B are used both for resistance and voltage measurement. For voltage measurements, a "+" polarity indication means that the red terminal is positive with respect to the center terminal.

"POLARITY" Lights: These are in the form of pilot light marked "+" and "-". They serve to indicate when the instrument is turned on as well as to indicate the polarity of a DC input. An indication of either "+" "-" may be obtained when the input is zero.

Measurement Readout

Read four (4) digits, two from each meter to obtain four places of information. Place the decimal as it is located in the range setting. If the right-hand meter reads 1-00 or above, the "1-" alone should be added (transferred) to the reading of the left-hand meter.

Examples: A reading of 27 and 1-03 should be read 2803.

A reading of 08 and 65 should be read 0865: on the 32.00K range of the 21B this would indicate 08.65K or 8.65 kilohms. (By retaining the first 0, the decimal is easily placed after the second figure just as it occurs in the range setting.)

THEORY OF OPERATION

Input Amplifier

The input amplifier is a tube-transistor circuit having high gain stability by virtue of a large amount of negative feed-back and stable feedback resistors. The amplifier consists of tube V1 and transistors Q1 through Q4. The two sections of V1 (a dual triode) comprise a balanced cathode follower input stage which "transforms" the high input-circuit impedance for driving the second stage. The second stage is also balanced, consisting of two transistors with a common large emitter resistor. These two transistors are placed in a common heat sink to minimize the possibility of drift from thermal effects. The following two stages are single ended.

Gain is controlled by varying the resistance in the feedback path. When the instrument is used as a voltmeter, "RANGE" switch S1 selects one of several resistive paths consisting of resistors R11 - R23. For operation as an ohmmeter, these same range resistors are used to furnish a constant input current to the junction of R8 and R10. Feedback then is obtained through the unknown resistor in such a way that the current through the unknown just balances the constant current through the range resistor. The resulting voltage drop across the unknown appears at the output of the amplifier to be measured by the digitizing and readout circuitry.

The input amplifier inverts the polarity of the input signal. When an appropriate range is selected, the amplifier's again will be such as to produce an output voltage which will be between -6.4 and +6.4 volts. Thus a full-scale input voltage or resistance on any range produces a 6.4 volt output which is negative when the input voltage is positive and vice versa.

Digitizing and Readout Circuits

The voltage from the input amplifier is broken down into 64 steps of 0.2 volt each by successively conparing it to six voltages obtained from a resistor matrix, R105, R106, and R135 - R162. The first such comparison is with a "0" voltage obtained from R105 and R106. This comparison determines the polarity of the input signal by determining whether the output of the input amplifier is above or below 0 volts.

The result of each comparison is a decision of whether or not to actuate a relay which then adds or subtracts to the voltage for all the following comparisons. Thus if the first comparison detects a negative signal voltage, (corresponding to a positive input), resistors R157 - R159 produce a voltage of -3.2 volts for the next comparison. If the signal voltage had been positive, this second comparison voltage would instead be +3.2 volts.

Similarly, the result of the second comparison determines the position of a second relay, K103, which adds or subtracts an additional 1.6 volts to produce a third comparison voltage (±3.2 ± 1.6 volts) from resistors R153 - R156. This process is repeated until, after six such comparisons, the signal voltage from the input amplifier is determined within 0.2 volt.

The resulting positions of the relays express the binary numbers from 000000 through 111111. The numbers 100000 to 111111 correspond to inputs of one polarity, while the numbers 000000 to 011111 correspond to inputs of the opposite polarity. The first of these digits, 0 to 1, is displayed as polarity information by the pilot lights. The remaining 32 numbers from 00000 to 11111 are displayed as 32 discrete positions of the left-hand meter. This is done by connecting weighting resistors to the relay contacts so that each relay contributes to the deflection of meter M102 according to that relay's binary value. Resistors R135 - R141 and R160 - R163 are used for this function also.

Another set of weighting resistors, R109 and R127 - R132 produces a similar quantized voltage for comparison with the signal from the input amplifier. Meter M101 is connected to read the difference between this quantized voltage and the signal voltage from the input amplifier. It thus provides an indication of the difference between the signal voltage and the value indicated by the step-wise meter, M102. It follows that the sum of the meter readings is proportional to the input voltage or resistance.

An understanding of the comparison circuits can be had by considering one of these six circuits separately. We may consider Q116 - Q118 and R124 - R126, which together form the comparison circuit that drives relay K107. A nearly-constant current of 2-1/2 ma is fed to the emitters of Q116 and Q117. Only one of these transistors will conduct, the one which has the more negative base voltage. But the base voltage of Q117 is the signal from the input amplifier while the base voltage of Q116 is a comparison voltage obtained from R135 - R141. Thus Q117 will conduct only if the signal voltage is below the comparison voltage, otherwise Q116 will conduct. When Q117 conducts it drives Q118 into conduction and this in turn causes relay K107 to operate.

As an example, the events which take place in measuring a positive input to the instrument that produces -5.5 volts input to the digitizing and readout circuitry are as follows:

> The positive input is inverted by the amplifier so that -5.5 volts appears at the base of the right-hand transistor of each comparator pair.
>
> Decision 1, -5.5v at the base of Q102 is below "0" volts at Q101 therefore K102 is not energized; providing -6.4 volts that is divided to -3.2 in resistors R157, 8, 9 for the succeeding comparators and the meters; red (plus) lamp lights and proper polarization is provided to meters by not energizing K101.

Decision 2, -5.5v at Q105 is lower than -3.2v at Q104 so K103 is energized; -1.6 is contributed to remaining comparators and the meters.

Decision 3, -5.5v at Q108 is lower than -4.8v at Q107 so K104 is energized; -.8v contributed to remaining comparators and the meters.

Decision 4, -5.5v at Q111 is not lower than -5.6v at Q110 therefore K105 is not energized; +.4v contributed to remaining comparators and the meters.

Decision 5, -5.5v at Q114 is less than -5.2v (sum of -3.2, 1.6, -8, +.4) at Q113 so K106 is energized; -.2v fed to Q116 and the meters.

Decision 6, -5.5v at Q117 is lower than -5.4 therefore K107 is energized contributing -.1v to M101.

The digitizing circuits have now approximated the -5.5 volts input to within .2 volts. The -.1v difference between the input and the quantized voltages for M101 established by weighting resistors R109 and R127-132 is resolved by M101 which serves as an analog vernier.

Regulated Power Supply

A Zener reference diode, CR205, is in one arm of a bridge consisting also of R217, R218, R220 and R222. R217 is a fixed resistor selected at the factory to set the power supply output to 12.8 volts (measured from -6.5 to +6.4 volt points). The output of the bridge is connected directly to the bases of Q207 and Q208. These balanced transistors amplify the error signal and feed it to Q204 and Q205 which in turn amplify the signal and apply it to Q203, thence to the series transistor Q202 which couples the rectifier output to the regulated +6.4 volt line.

The junction of R219 and R221 is midway between the +6.4 and -6.4 volt lines and therefore is used as the "0" volt reference with respect to which all other voltages are measured. Note, however, that this junction has an output impedance of 200Ω so that any measurements made from this reference should be made with a high impedance meter; preferably ten megohms or more. Also note that this "0" voltage reference is connected to the center input terminal on the panel only when the range switch is at a VOLTS setting. Thus the center input terminal should not be regarded as an electronic ground for maintenance measurements of the instrument's circuit.

An additional regulated power supply is used to supply +50 volts to the tube plates, the comparison circuits and the low-voltage regulator. Here again an error voltage is obtained from a bridge. In this case the 12.8 volt output from the low voltage supply forms one arm of the bridge,

the high voltage supply forms another arm and R215 and R216 form the remaining two arms. The bridge output is applied to the base of Q206 which acts as an emitter follower to drive series transistor Q201. Q201 provides variable coupling from the negative output of the rectifier circuit to the +6.4 volt line so that the high voltage supply is effectively in series with the low voltage supply.

Resistor R224 and silicon rectifier CR206 are in series with the negative lead from the low voltage rectifier circuit to provide additional negative voltages 7.1 to 8.0 volts. These voltages are not critical and are not highly regulated. CR206 is operated only in its forward direction to give a voltage drop of about 0.9 volt; it does not act as a rectifier.

Periodic Maintenance

This type of maintenance operation is not required other than to provide assurance of the calibration accuracy of the instrument.

It is recommended that a regular check of calibration be performed to provide the user assurance that the calibration is correct. The frequency of such checks will depend upon the level of confidence that is desired. Simple checks against a fixed resistor or standard voltage can be made daily if desired.

Complete calibration might be anything from a monthly to an annual process. In any case, the following procedure is recommended:

Calibration and Checkout - Model 21B

1. Remove rear cover. Set front-panel mechanical zero adjustments of meters with meter terminals shorted and with power off. It is very important that this be done accurately.

2. Check voltage from -6.4 to +6.4 volt lines (available at R219 and R221) -- should be between 12.79 and 12.81 volts. Replace R217 with appropriate value wirewound resistor between 0 and 56 ohms if necessary.

3. Set R160 (600Ω trimmer, rear board) to calibrate left-hand meter (M102). Using a variable input, set this trimmer so that all 32 meter positions are distinct and unambiguous. To do this it may be necessary to compromise so that pointer is slightly low on some steps and slightly high on others.

4. Set R108 (50Ω trimmer, rear board) so that the right-hand meter (M101) drops just 100 points as M102 steps from 00 to 01. Do not vary the input to obtain the step; short Q118 from base to either collector or emitter to cause the step to occur one way or the other.

5. Check operation of relays. Relays should operate between 00 and 15 and between 1-00 and 1-20 as read on M101. If relays operate outside of this range it will not affect accuracy but will make readout difficult.

6. Check for grid current: Switch from the highest voltage range to the lowest voltage range with input terminals open. Right-hand meter should move about 1/2 division or less. DO NOT REPLACE THE TUBE ROUTINELY. Tubes very rarely fail in this instrument and replacements may be inferior. If necessary to replace the 12AU7, use an aged tube to obtain low

grid current. Telefunken tubes (12AU7/ECC82) are recommended for this instrument because of low drift and low grid current. Even so it is occasionally necessary to reject a Telefunken tube for excessive drift. Tubes should be aged 48 hours at 100 plate volts, 10 ma. Operation in the instrument does not provide adequate aging. Aged and selected tubes may be obtained from J-Omega Company.

7. Check accuracy of resistor set R109 and R127-R132: With instrument carefully zeroed on highest voltage range, cause the polarity indication to reverse by shorting Q103 from base to either emitter or collector. A shift from zero of more than about 1/2 division on the right-hand meter indicates the need for a high-resistance trimming resistor shunting R109 or R127 (depending on direction of shift). Such a resistor should not be lower than about 100 kilohms. Large shifts (several divisions) may indicate need for replacing the set R109 and R127-R132. Before trimming or replacing these resistors make sure that the error is not due to excessive relay contact resistance, especially in K102 and K103.

8. With input shorted, move the range switch from the 3.2 volt position to the 3200 volt position after the instrument has been carefully zeroed. A shift of more than 1/2 division will indicate the need for shunting R219 or R221, depending on the direction of shift. Excessive shift may indicate the need for replacing resistor R219 or R221.

9. Type 21B

Calibrate resistance ranges. Use fixed precision resistors near 300Ω, 3K, 30K, etc. Calibration trimmers are on front circuit board as follows:

Range	Trimmers
320Ω	Fixed - replace R20 if necessary
3200Ω	Fixed - replace R21 or R23 if necessary
32K (3200V)	Fixed - replace R15 if necessary
320K (320V)	R18 5K
3.2M (32V)	R17 50K
32M (3.2V)	R16 500K
all VOLTS	R8 250K

Using an accurate voltage source of 300 or 320 volts, set the 320.0 volt range using trimmer R8. Check accuracy of other voltage ranges.

If voltage measurements are more important than resistance measurements, it is now permissible to readjust R16-R18 slightly to improve accuracy of voltage readings.

Type 21BV

Calibrate voltage ranges. Use a precision voltage source (.01%) having the following voltages: 3000 or 3200V, 300 or 320V, 30 or 32V, 0.3 or 0.32V.

Calibration trimmers are on front circuit board as follows:

Range	Trimmers
3200V	R8 250K (adjust first as it affects all ranges)
320V	R18 5K
32V	R17 50K
3.2V	R16 500K (also affects 320Mv range)
320 Mv	R37 50K

Trouble Shooting

In trouble shooting, the rear circuit board may be removed and laid on the service bench without disconnection. This will make nearly all parts of the instrument highly accessible while the instrument is operating. This may also be done during calibration to make the calibration adjustments more accessible.

For trouble shooting it is recommended that a high-impedance voltmeter be used, preferably 10 megohms or more. (For step 2 above it is permissible to use an accurate type low-impedance meter.)

NOTE: The center input terminal is connected to the "0" volt reference only on VOLTS ranges. When trouble shooting, clip on to the junction of R219 and R221 to obtain the "0" volt reference; do not use the center INPUT terminal.

Relay covers may be removed for contact cleaning and adjustment. This should be considered whenever erratic readings are obtained. Starting with relay K102, the lowest numbered relays carry the most current for the resistor matrix and are therefore most subject to contact voltage drop. Paralleled pairs of contacts drive the resistor matrix although for simplicity they are shown as single contacts on the diagram.

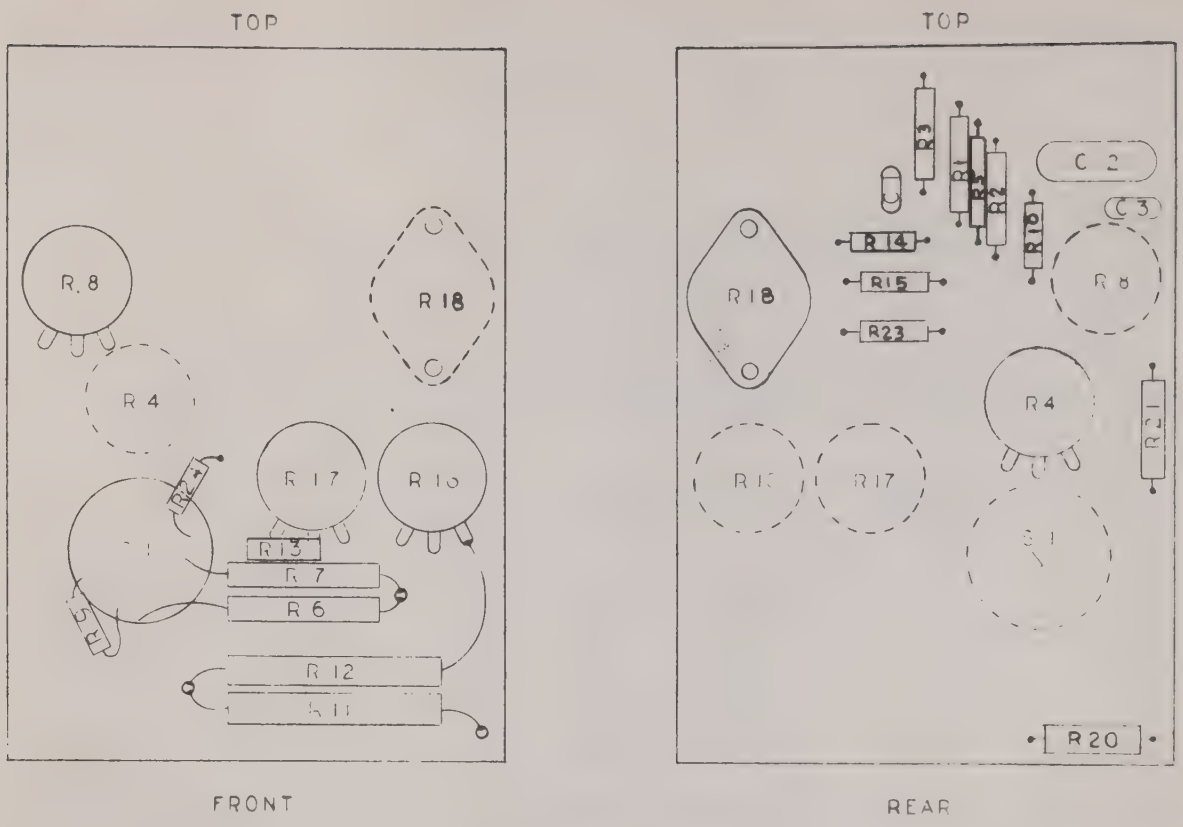
Probably the most common cause of failure is a shorted transistor, Q4, caused by applying an excessive input voltage when the range switch is set to a low ohms range. When Q4 is shorted, the instrument continually reads off-scale positive. Q4 has been provided with a socket for easy testing and replacement. Further damage may occur if the input voltage is very high or if high input current is available, but this is more rare. Other components subject to damage include Q101 through Q118 and the range resistor involved (such as R21 or R15).

The following transistors are matched pairs and should be replaced as pairs. Pairs are available from J-Omega Company:

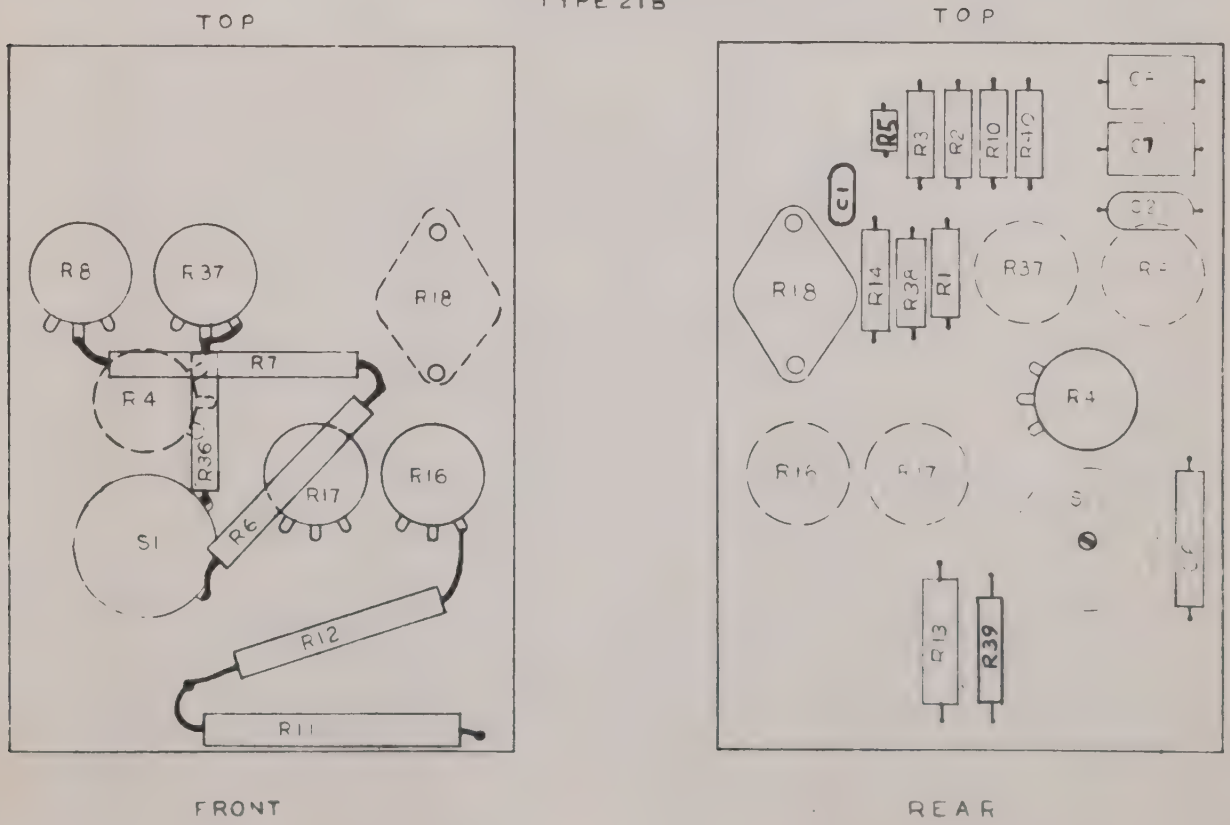
Q101 and Q102
Q104 and Q105
Q107 and Q108
Q110 and Q111
Q113 and Q114
Q116 and Q117
Q207 and Q208

Any of these pairs may be replaced independently of the other pairs.

Transistor pairs are matched for equal (±2mv) base-emitter voltage at 1.25 ma collector current, at equal temperatures.



PARTS LOCATION
FRONT CIRCUIT BOARD
TYPE 21B



PARTS LOCATION
FRONT CIRCUIT BOARD
TYPE 21BV

PARTS LIST

	CAPACITORS	Mfr & P/N	Quan
C1	.04mf, 100v mylar	Elmenco 1DP-1-403	1
C2	.027mf, 600v mylar-paper	Elmenco 6DP-3-273	1
C3	.01mf, 400v mylar-paper	Elmenco 4DP-1-103	1
C4	2.2mf, 3v ceramic disc	Sprague 41C171	2
C5	.25mf, 100v mylar	Elmenco 1DP-3-254	1
C101	25mf, 6v electrolytic	J-Omega P5050	1
C201	900mf, 35v electrolytic	J-Omega P5017	1
C202	5mf, 25v electrolytic	J-Omega P5056	1
C203	150mf, 15v electrolytic	J-Omega P5042	1
C204	18mf, 100v electrolytic	J-Omega P5044	1
C205	same as C4		
C206	.1mf, 100v mylar	Elmenco 1DP-2-104	1

	RECTIFIERS & DIODES	Mfr & P/N	Quan
CR1	1N34A or similar	Sylvania	7
CR101	same as CR1		
CR102	same as CR1		
CR103	same as CR1		
CR104	same as CR1		
CR105	same as CR1		
CR106	same as CR1		
CR201	1N3193	R.C.A.	5
CR202	same as CR201		
CR203	same as CR201		
CR204	same as CR201		
CR205	1N2166A	US Sem Cor	1
CR206	same as CR201		

	TRANSISTORS	Mfr & P/N	Quan
Q1, Q2	matched pair 2N404	J-Omega P3025	2
Q3	2N1309 or selected 2N404	J-Omega P3021	1
Q4	2N3053 or 2N3415	R.C.A. G.E.	1
Q101, Q102	matched pair 2N404	J-Omega P3024	6
Q103	2N3392	G.E.	8
Q104, Q105	same as Q101,102		
Q106	same as Q103		
Q107, Q108	same as Q101,102		
Q109	same as Q103		
Q110, Q111	same as Q101,102		

	TRANSISTORS	Mfr & P/N	Quan
Q112	same as Q103		
Q113 > Q114	same as Q101,102		
Q115	same as Q103		
Q116 > Q117	same as Q101,102		
Q118	same as Q103		
Q201	2N1183	R.C.A.	1
Q202	2N3613	Motorola	1
Q203	2N404	Texas Inst.	2
Q204	same as Q103		
Q205	same as Q103		
Q206	same as Q203		
Q207 > Q208	same as Q1,2		

	RESISTORS	Mfr & P/N	Quan
R1	film type, 100K, 1/2w, 1%	Electra MF7C	2
R2	composition, 22M, 1/2w, 10%	Allen-Bradley Type EB	1
R3	film type, 10K, 1/2w, 1%	Electra MF7C	2
R4	10-turn, 50K	J-Omega P4047	1
R5	same as R3		
R6	metal film, 4.95M, 2w, 1%	J-Omega P4032	2
R7	same as R6		
R8	variable, 250K composition	J-Omega P4046	1
R9	composition, 3.9M, 1/2w, 10%	Allen-Bradley Type EB	1
R10	composition, 4.7M, 1/2w, 10%	Allen-Bradley Type EB	1
R11	metal film, 9.9M, 2w, 1%	J-Omega P4033	2
R12	same as R11		
R13	metal film, 1.98M, 1w, 1%	J-Omega P4034	1
R14	metal film, 196K, 1/2w, 1%	J-Omega P4035	1
R15	wirewound, 18K, .02%	J-Omega P4053	1
R16	variable, 500K composition	J-Omega P4043	1
R17	variable, 50K composition	J-Omega P4044	1
R18	variable, 5K wirewound	CTS/IRC 112-5000	1
R20	wirewound, 320K, .02%	J-Omega P4061	1
R21	wirewound, 10,666.7K, .02%	J-Omega P4062	1
R23	wirewound, 2,461.54K, .02%	J-Omega P4063	1
R24	composition, 680K, 1/2w, 10%	Allen-Bradley Type EB	1

	RESISTORS	Mfr & P/N	Quan
R25	film type, 12.7K, 1/2w, 1%	Electra MF7C	5
R26	same as R25		
R27	same as R25		
R28	film type, 31.6K, 1/2w, 1%	Electra MF7C	1
R29	film type, 475Ω, 1/2w, 1%	Electra MF7C	4
R30	film type, 261Ω, 1/2w, 1%	Electra MF7C	2
R31	composition, 1.5K, 1/2w, 10%	Allen-Bradley Type EB	4
R32	same as R31		
R33	composition, 10Ω, 1/2w, 10%	Allen-Bradley Type EB	4
R34	same as R33		
R35	same as R25		
R101	composition, 10K, 1/2w, 5%	Allen-Bradley Type EB	1
R102	film type, 100Ω, 1/2w, 1%	Electra MF7C	1
R103	composition, 6.8K, 1/2w, 10%	Allen-Bradley Type EB	1
R104	film type, 51.1K, 1/2w, 1%	Electra MF7C	6
R105	film type, 400Ω, 0.1%	J-Omega P4070	9
R106	same as R105		
R107	film type, 1.33K, 1/2w, 1%	Electra MF7C	6
R108	variable, 50Ω, wire-wound	CTS/IRC 112-50	1
R109	film type, 6.4K, 0.1%	J-Omega P4074	6
R110	same as R1		
R111	same as R30		
R112	same as R104		
R113	same as R107		
R115	same as R104		
R116	same as R107		
R118	same as R104		
R119	same as R107		
R121	same as R104		
R122	same as R107		
R124	same as R104		
R125	same as R107		
R127	wirewound 200Ω, .02%	J-Omega P4064	1
R128	wirewound, 400Ω, .02%	J-Omega P4065	1
R129	wirewound, 800Ω, .02%	J-Omega P4066	1
R130	film type, 1.6K, 0.1%	J-Omega P4072	6

	RESISTORS	Mfr & P/N	Quan
R131	film type, 3.2K, 0.1%	J-Omega P4073	5
R132	same as R109		
R135	same as R109		
R136	same as R109		
R137	film type, 213.33Ω, 0.1%	J-Omega P4069	1
R138	same as R105		
R139	film type, 800Ω, 0.1%	J-Omega [illegible]	6
R140	same as R13[illegible]		
R141	same as R131		
R142	same as R109		
R143	same as R109		
R144	same as R105		
R145	same as R139		
R146	same as R130		
R147	same as R131		
R148	same as R131		
R149	same as R131		
R150	same as R105		
R151	same as R139		
R152	same as R130		
R153	same as R130		
R154	same as R130		
R155	same as R105		
R156	same as R139		
R157	same as R139		
R158	same as R139		
R159	same as R105		
R160	variable, 600Ω, wire-w.	CTS/IRC 112-600	1
R161	film type, 6.04K, 1/2w 1%	Electra MF7C	2
R162	same as R161		
R163	film type, 402K, 1/2w, 1%	Electra MF7C	1
R201	composition, 33Ω, 1/2w, 10%	Allen-Bradley Type EB	1
R202	wirewound, 10Ω, 1/2w, 10%	IRC BHW	1
R203	composition, 15K, 1/2w, 10%	Allen-Bradley Type EB	1
R204	same as R33		
R205	same as R31		
R206	composition, 4.7K, 1/2w, 10%	Allen-Bradley Type EB	2
R207	composition, 39K, 1/2w, 10%	Allen-Bradley Type EB	1
R208	same as R33		
R209	same as R29		
R210	same as R206		
R211	film type, 931Ω, 1/2w, 1%	Electra MF7C	1

	RESISTORS	Mfr & P/N	Quan
R212	same as R29		
R213	same as R29		
R214	same as R31		
R215	same as R25		
R216	film type, 3.48K, 1/2w, 1%	Electra MF7C	1
R217	stable type, value selected in manufacture		1
R218	film type, 316Ω, 1/2w, 1%	Electra MF7C	1
R219	same as R105		
R220	wirewound, 150Ω, 1%	J-Omega P4080	1
R221	same as R105		
R222	wirewound, 50Ω, 1%	J-Omega P4081	1
R224	composition, 1Ω, 1/2w, 10%	Allen-Bradley Type EB	1

	OTHER COMPONENTS		
F201	fuse, 3/10 amp, Slo-Blo (1/4 amp for 220v models)	Littlefuse	1
I101	lamp, 14.4v	G.E. 1813	2
I102	same as I101		
XI101	pilot light, red (+)	J-Omega P8030	1
XI102	pilot light, white (-)	J-Omega P8031	1

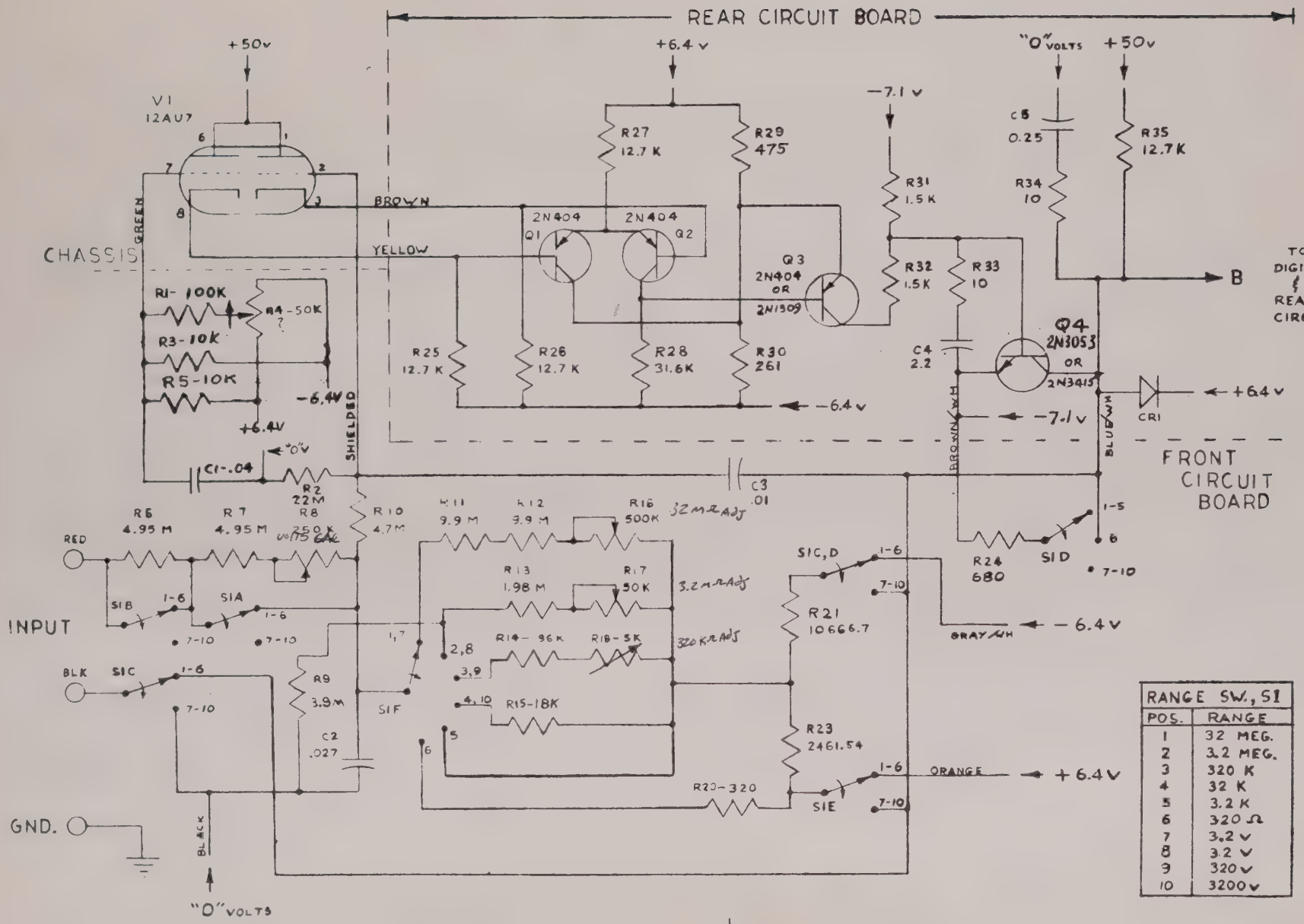
	OTHER COMPONENTS	Mfr & P/N	Quan
K101	relay, 4pdt	J-Omega P7010	2
K102	same as K101		
K103	relay, dpdt	J-Omega P7011	5
K104	same as K103		
K105	same as K103		
K106	same as K103		
K107	same as K103		
M101	meter, analog	J-Omega P7101	1
M102	meter, digital	J-Omega P7102	1
S1	switch, ten position rotary	J-Omega P7021	1
S201	switch, toggle, spst	Cutler-Hammer 8280-K15	1
T201	transformer, 115v primary	J-Omega P6111	1
	(option) 230v primary	J-Omega P6112	
V1	tube, 12AU7 (aged, low drift)	Telefunken P3002	1

AUXILIARY PARTS LIST
TYPE 21BV

(Delete the following from the 21B parts list: C3, R9, R15, R20, R21, R23 and R24.)

	CAPACITORS	Mfr & P/N	Quan
C6	.15mf, 600v, mylar	Elmenco 6DP-5-154	1
C7	3900mmf, 500v, poly-styrene	Centralab CPR-3900J	1
C8	6200mmf, 500v, poly-styrene	Centralab CPR-6200J	1

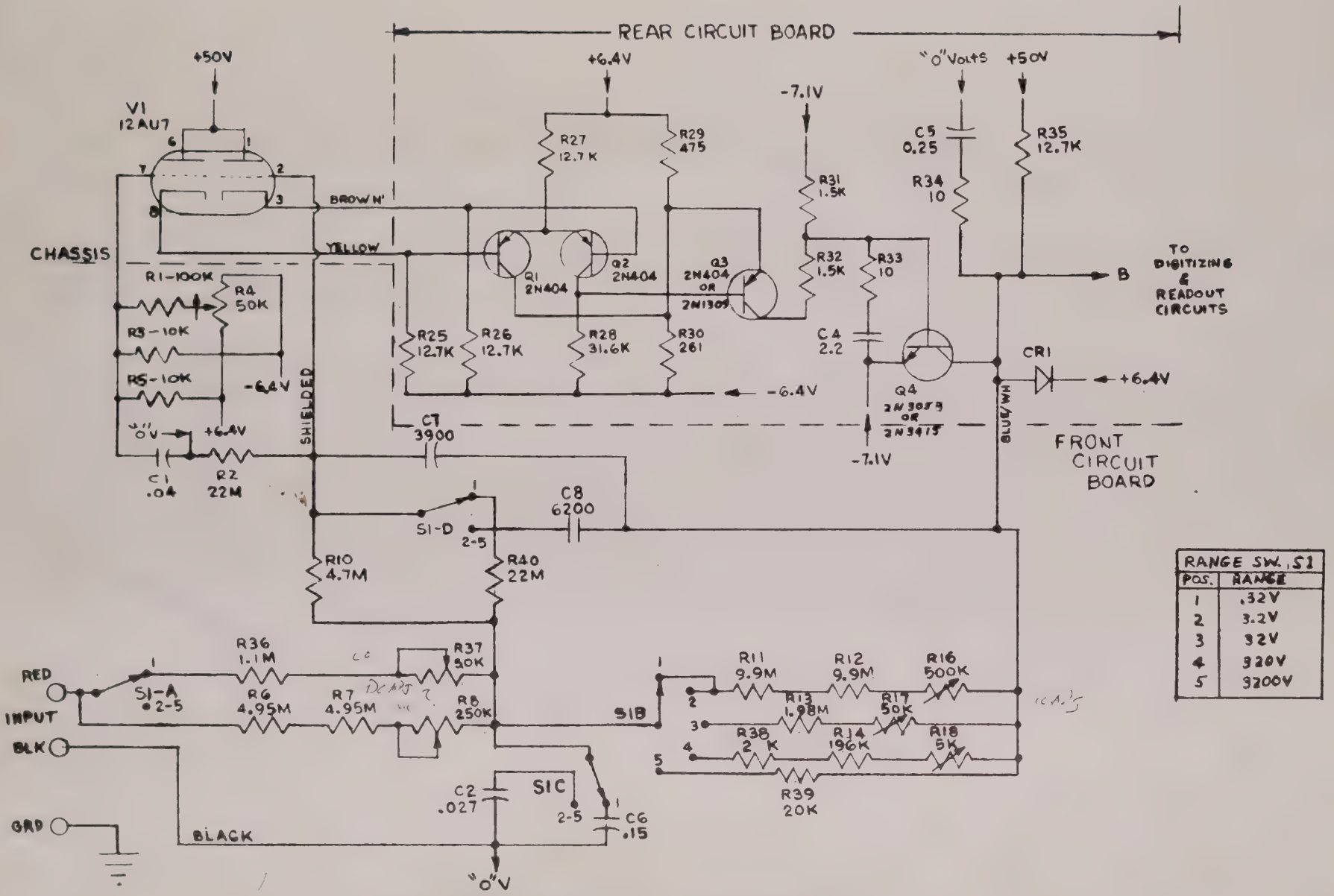
	RESISTORS	Mfr & P/N	Quan
R36	dep. carbon 1.1M, 1/2w, 1%	IRC MEC-T2	1
R37	same as R17		2
R38	dep. carbon, 2K, 1/2w, 1%	Electra MF7C	1
R39	wirewound, 20K, .02%	J-Omega P4067	1
R40	composition, 22M, 1/2w, 10%	Allen-Bradley Type EB	2



RANGE SW., S1	
POS.	RANGE
1	32 MEG.
2	3.2 MEG.
3	320 K
4	32 K
5	3.2 K
6	320 Ω
7	3.2 V
8	3.2 V
9	320 V
10	3200 V

21B INPUT AMPLIFIER & RANGE SWITCH

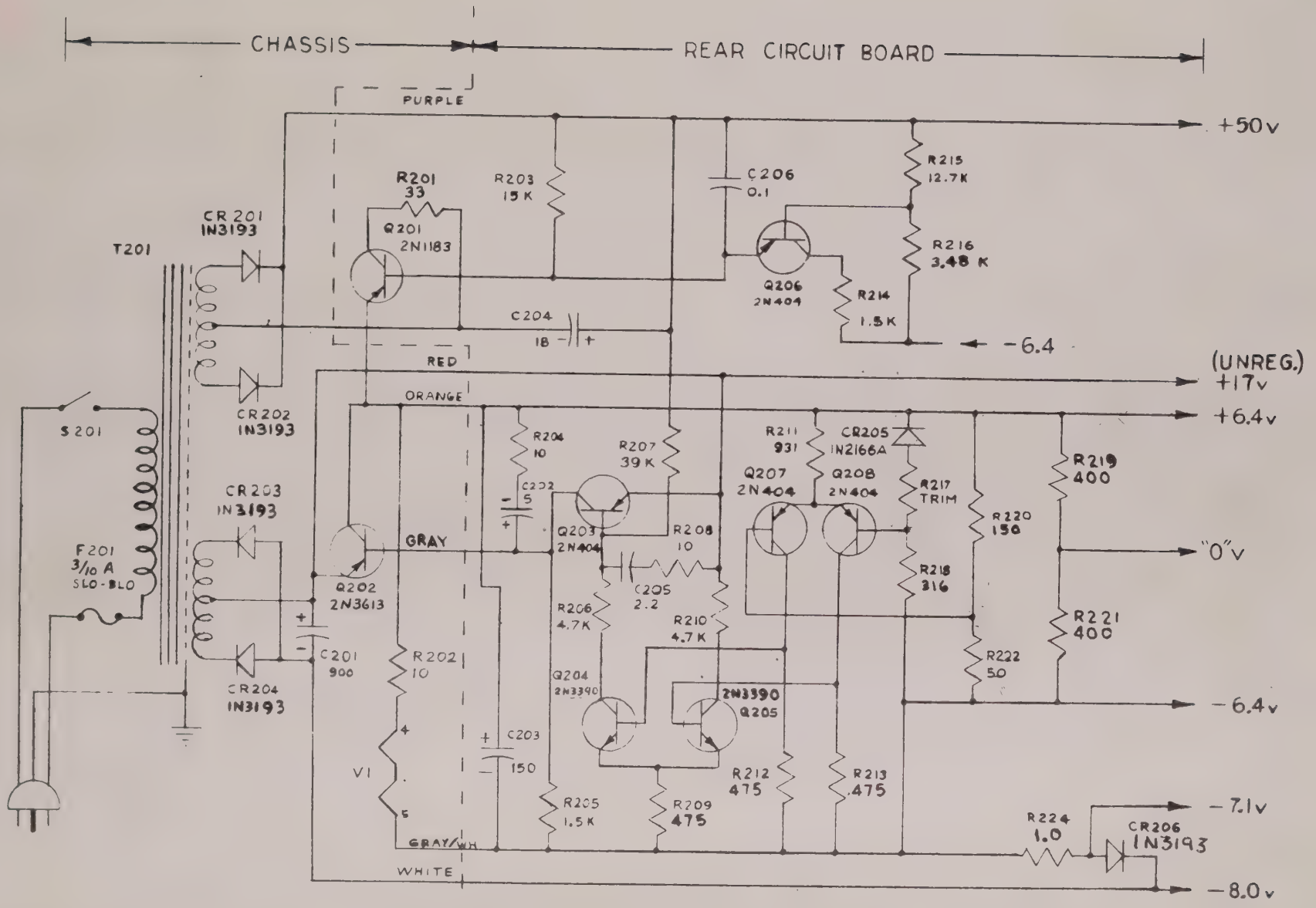
5/24



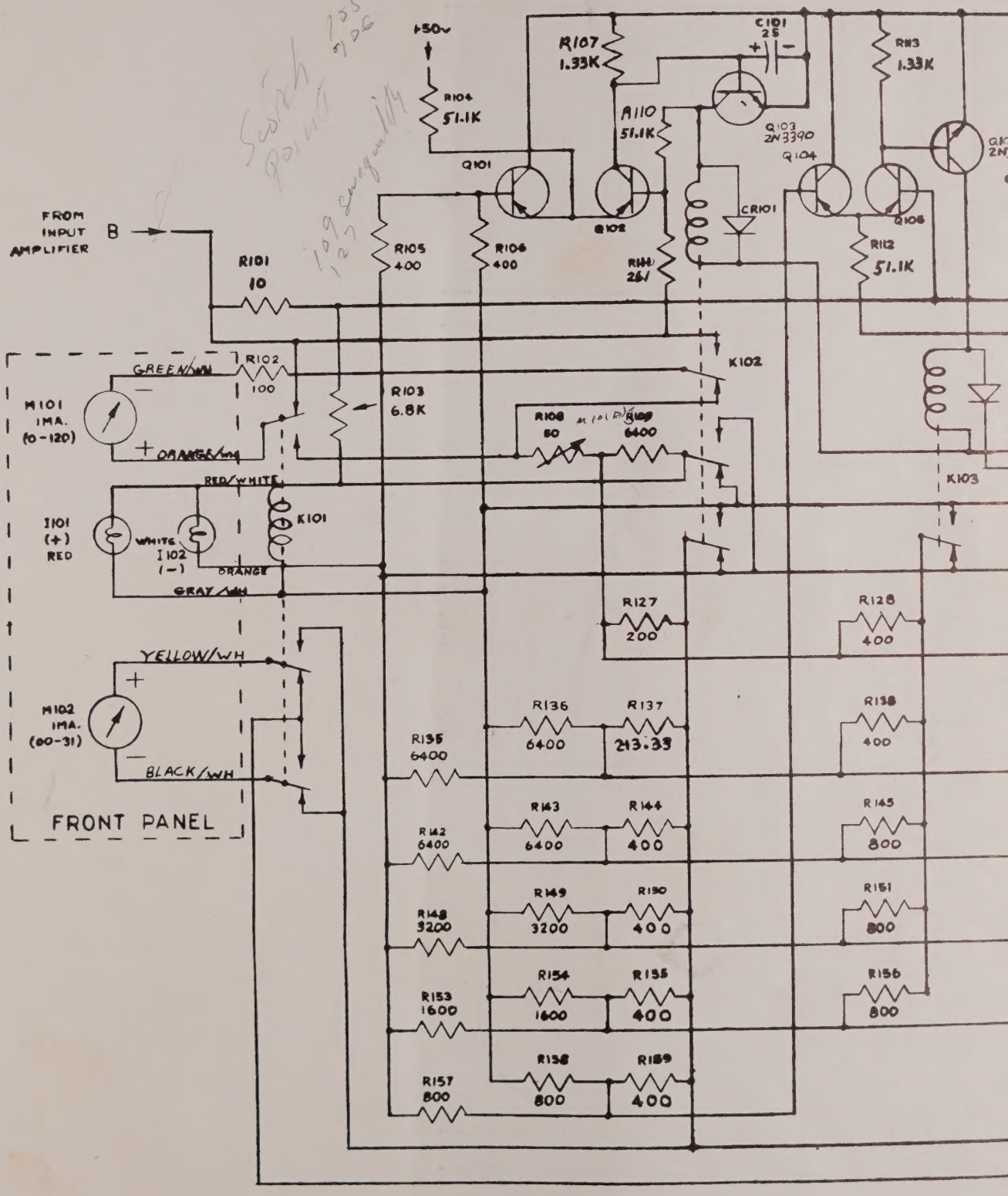
RANGE SW. S1	
POS.	RANGE
1	.32V
2	3.2V
3	32V
4	320V
5	3200V

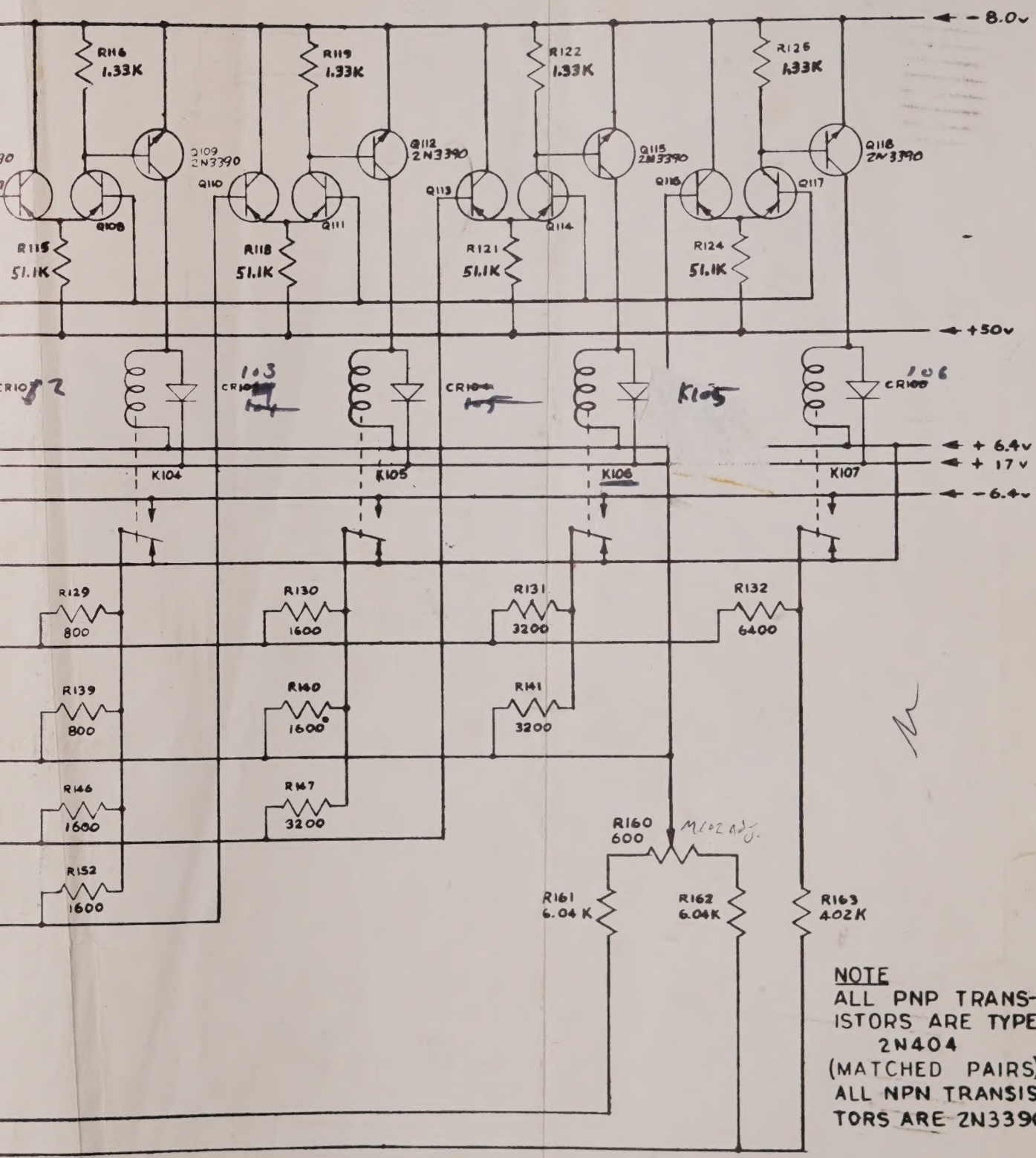
21 BV INPUT AMPLIFIER & RANGE SWITCH

S124



REGULATED POWER SUPPLY


+150v
R104
51.1K
R107
1.33K
C101
25
+
-
R113
1.33K
A110
51.1K
Q103
2N3390
Q104
Q101
Q102
CR101
Q106
R112
51.1K
FROM
INPUT
AMPLIFIER
B
R101
10
R105
400
R106
400
R111
261
K102
K103
R102
100
GREEN/WH
M101
1MA.
(0-120)
ORANGE/WH
R103
6.8K
R108
50
R109
6400
RED/WHITE
K101
I101
(+)
RED
WHITE
I102
(-)
ORANGE
GRAY/WH
R127
200
R128
400
YELLOW/WH
M102
1MA.
(00-31)
BLACK/WH
R136
6400
R137
213.33
R138
400
R135
6400
R143
6400
R144
400
R145
800
R142
6400
R149
3200
R150
400
R151
800
R148
3200
R154
1600
R155
400
R156
800
R153
1600
R158
800
R159
400
R157
800
FRONT PANEL



NOTE
ALL PNP TRANSISTORS ARE TYPE 2N404 (MATCHED PAIRS)
ALL NPN TRANSISTORS ARE 2N3390